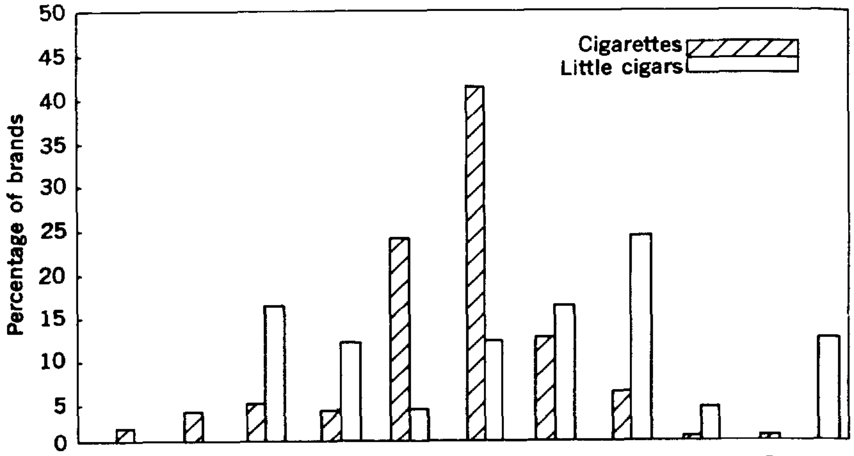
Figure 5.—Percent distribution of 130 brands of cigarettes and 25 brands of little cigars by nicotine content.



Mg. nicotine	0.00–0.24	0.25–0.49	0.50–0.74	0.75–0.99	1.00–1.24	1.25–1.49	1.50–1.74	1.75–1.99	2.00–2.24	2.25–2.49	2.50+
Cigarettes	2.3	3.9	4.6	3.9	23.9	40.8	12.3	5.4	1.5	1.5	0
Little Cigars	0	0	16.0	12.0	4.0	12.0	16.0	24.0	4.0	0	12.0

SOURCE: U.S. Department of Health, Education, and Welfare (97) and Federal Trade Commission (34).

TABLE 37.—*Shipment of small and large cigars destined for domestic consumption (1970, 1971, 1972)*

Year	1970	1971	1972
Small cigars			
January	58, 328, 520	85, 753, 780	123, 477, 550
February	63, 431, 580	72, 092, 205	179, 817, 839
March	85, 881, 860	46, 542, 800	198, 165, 593
April	101, 613, 500	59, 059, 920	125, 335, 740
May	81, 093, 180	93, 237, 473	159, 334, 565
June	82, 471, 120	94, 560, 140	180, 582, 243
Subtotal	472, 819, 760	451, 246, 318	966, 713, 530
July	62, 143, 140	70, 332, 500	127, 713, 320
August	68, 220, 365	127, 709, 310	670, 936, 869
September	79, 101, 045	95, 027, 340	422, 534, 705
October	90, 752, 880	109, 567, 900	708, 116, 830
November	64, 290, 600	106, 666, 107	551, 326, 888
December	63, 806, 010	123, 809, 553	485, 587, 014
Subtotal	428, 314, 040	633, 112, 710	2, 966, 215, 626
Yearly total	901, 133, 800	1, 084, 359, 028	3, 932, 929, 156
Large cigars			
January	581, 742, 001	573, 039, 120	534, 565, 488
February	595, 249, 522	586, 810, 844	562, 414, 577
March	629, 977, 375	665, 998, 099	654, 827, 796
April	652, 800, 200	655, 850, 213	554, 242, 048
May	748, 040, 796	670, 064, 933	719, 489, 529
June	644, 539, 031	692, 436, 529	578, 501, 068
Subtotal	3, 852, 348, 925	3, 844, 199, 738	3, 604, 040, 506
July	647, 397, 547	619, 838, 386	520, 873, 339
August	673, 082, 971	662, 970, 148	682, 331, 630
September	721, 561, 449	680, 476, 418	594, 843, 957
October	797, 601, 253	679, 420, 968	693, 150, 668
November	696, 526, 464	742, 948, 802	650, 746, 540
December	596, 244, 159	516, 879, 415	437, 429, 996
Subtotal	4, 132, 413, 843	3, 902, 534, 137	3, 579, 356, 130
Yearly total	8, 084, 762, 768	7, 746, 733, 875	7, 183, 396, 636

Source: U.S. Department of the Treasury *(101)*.

TABLE 38.—*Selected compounds in mainstream smoke*

Smoke compound	Cigarette A (nonfilter)	Cigarette B (filter)	Little cigar A	Little cigar B	Small cigar C
"Tar", milligram per cigarette	36. 1	20. 3	17. 4	31. 8	40. 6
Nicotine, milligram per cigarette	2. 7	1. 4	. 6	1. 8	3. 1
Carbon monoxide, volume percent	4. 6	4. 5	5. 3	11. 1	7. 7
Carbon dioxide, volume percent	9. 4	9. 6	8. 5	13. 2	12. 7
Reducing sugars, percent of tobacco weight	9. 3	7. 9	1. 5	2. 9	2. 7
Hydrogen cyanide, microgram per cigarette	536. 0	361. 0	381. 0	697. 0	1, 029. 0
Acetaldehyde, microgram per cigarette	770. 0	774. 0	630. 0	1, 238. 0	1, 150. 0
Acrolein, microgram per cigarette	105. 0	71. 0	41. 0	54. 0	66. 0
Total pyridines, micrograms per cigarette	82. 8	27. 3	58. 0	85. 3	80. 3
Phenol, microgram per cigarette	124. 2	33. 0	35. 1	63. 4	94. 1
Benz(a)anthracene, nanogram per cigarette	74. 0	31. 0	34. 0	25. 0	39. 0
Benzo(a)pyrene, nanogram per cigarette	47. 0	20. 0	18. 0	22. 0	30. 0

Source: Hoffmann, D., Wynder, E. L. (*44*).

TABLE 39.—*The pH of the mainstream smoke of selected tobacco products*

[Numbers in parentheses indicate number of last puff.]

Average pH	Cigarette A (nonfilter)	Cigarette B (filter)	Little cigar A	Little cigar B	Small cigar C	Cigar D
3d puff	6. 19	6. 15	6. 44	6. 55	6. 53	6. 47
5th puff	6. 14	6. 12	6. 34	6. 46	6. 49	--------
7th puff	6. 09	6. 01	7. 03	6. 51	6. 56	--------
9th puff	6. 02	5. 83	--------	6. 98	6. 59	6. 27
13th puff	--------	--------	--------	--------	--------	6. 39
18th puff	--------	--------	--------	--------	--------	6. 41
23d puff	--------	--------	--------	--------	--------	6. 81
28th puff	--------	--------	--------	--------	--------	7. 22
33d puff	--------	--------	--------	--------	--------	7. 53
38th puff	--------	--------	--------	--------	--------	7. 78
Last puff	5. 96(11)	5. 76(10)	7. 73 (8)	7. 25(10)	7. 11(11)	7. 96(43)

Source: Hoffmann, D., Wynder, E. L. (*44*).

Conclusions

Pipe and cigar smokers in the United States as a group experience overall mortality rates that are slightly higher than those of nonsmokers, but these rates are substantially lower than those of cigarette smokers. This appears to be due to the fact that the total exposure to smoke that a pipe or cigar smoker receives from these products is relatively low. The typical cigar smoker smokes fewer than five cigars a day and the typical pipe smoker smokes less than 20 pipefuls a day. Most pipe and cigar smokers report that they do not inhale the smoke. Those who do inhale, inhale infrequently and only slightly. As a result, the harmful effects of cigar and pipe smoking appear to be largely limited to increased death rates from cancer at those sites which are exposed to the smoke of these products. Mortality rates from cancer of the oral cavity, intrinsic and extrinsic larynx, pharynx, and esophagus are approximately equal in users of cigars, pipes, and cigarettes. Inhalation is evidently not necessary to expose these sites to tobacco smoke. Although these are serious forms of cancer, they account for only about 5 percent of the cancer mortality among men.

Coronary heart disease, lung cancer, emphysema, chronic bronchitis, cancer of the pancreas, and cancer of the urinary bladder are diseases which are clearly associated with cigarette smoking, but for cigar and pipe smokers death rates from these diseases are not greatly elevated above the rates of nonsmokers. These diseases seem to depend on moderate to deep inhalation to bring the smoke into direct contact with the issue at risk or to allow certain constituents, such as carbon monoxide, to be systematically absorbed through the lungs or to affect the temporal patterns of absorption of other constituents such as nicotine that can be absorbed either through the oral mucosa or through the lungs. Evidence from countries where smokers tend to consume more cigars and inhale them to a greater degree than in the United States indicates that rates of lung cancer become elevated to levels approaching those of cigarette smokers.

Available data on the chemical constituents of cigar, pipe, and cigarette smoke suggest that there are marked similarities in the composition of these products. Pipe and cigar smoke, however, tends to be more alkaline than cigarette smoke, and fermented tobaccos commonly used in pipes and cigars contain less reducing sugars than the rapidly dried varieties commonly used in cigarettes.

Experimental evidence suggests that little difference exists between the tumorigenic activities of tars obtained from cigar or cigarette tobaccos. Malignant skin tumors appear somewhat more rapidly and in larger numbers in animals whose skin has been painted with cigar tars than in those animals painted with cigarette tars.

One must conclude that some risk exists from smoking cigars and pipes as they are currently used in the United States, but for most diseases this is small compared to the risk of smoking cigarettes as they are commonly used. Nevertheless, changes in patterns of usage that would bring about increased exposure either through increased individual use of cigars and pipes or increased inhalation of pipe and cigar smoke have the potential of producing risks not unlike those now incurred by cigarette smokers. Mechanical or chemical modifications of pipe tobacco and cigars that would result in a smoke more compatible with inhalation could have this effect.

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CHAPTER 7

Exercise Performance

Contents

Introduction

Although it has long been held by athletes and coaches that cigarette smoking is associated with "shortness of wind" and impaired performance, until recently there has been little scientific evidence to support this view. In the past few years, a variety of studies have appeared dealing with the effect of cigarette smoking on the response of man to exercise. The following is a review of these studies.

Age, sex, training, health, weight, and other factors are known to influence exercise performance. Because most of the investigations were carried out in healthy, young male volunteers, the groups were quite comparable with regard to age, sex, and health; however, weight, training, and other factors were often inadequately controlled. Furthermore, problems in study design and statistical analysis limit the value of several of these studies.

Many forms of exercise were performed in these experiments, including: pedaling a bicycle ergometer, running on a treadmill, running on a track, swimming, step climbing, gripping a hand dynamometer, and doing several different exercise activities as part of a battery of tests. Small to maximum amounts of work were carried out in the various studies revewed.

Studies of Smokers

Most of the studies of habitual cigarette smokers followed a similar format with respect to smoking: (*a*) The subjects refrained from smoking for a few hours prior to testing, and (*b*) two test runs were performed, one without smoking and one in which smoking immediately preceded the exercise or was incorporated with the exercise protocol.

Several investigators (*1*, *15*, *28*) studied the effect of smoking on maximum grip strength. Willgoose (*28*) reported a greater mean percent recovery of grip strength after the nonsmoking trial than after the smoking trial. Kay and Karpovich (*15*) and Anderson and Brown (*1*) all followed a protocol similar to that of Willgoose except that they randomized the smoking and nonsmoking trials, and substituted a "placebo" cigarette for the nonsmoking trial. In neither of these studies were statistically significant differences observed between the grip scores for the smoking and nonsmoking trials.

Reeves and Morehouse (*24*) administered a battery of tests to 15 colleges students. The tests were: A tapping test, a strength test, a jumping test, and the short form of the Harvard step test. No statistically significant differences in performance were noted under conditions of smoking or nonsmoking.

A total of 32 college students from intermediate swimming classes abstained from smoking for 15 minutes, 2 hours, and 12 hours in a study conducted by Pleasants, et al. (*23*). Following the abstinence, they swam distances of 100 and 200 yards. Although actual swimming times were not published, the authors reported no statistically significant differences between the mean swimming times after the different periods of abstinence for either distance.

In 1946, Juurup and Muido (*13*) carried out several experiments in which three young cigarette smokers exercised on a Krogh's bicycle ergometer. Smoking was found to increase the pulse rate at rest as well as during exercise. Although the effect was less consistent than on the heart rate, smoking was also associated with elevated blood pressure. Smoking had no effect on oxygen consumption. Henry and Fitzhenry (*12*), in 1949, using the bicycle ergometer, also found that smoking exerted no effect on oxygen consumption. In the same year, Karpovich and Hale (*14*) studied bicycle ergometer performance in eight young men. In all subjects, the average riding time was better in nonsmoking tests than in smoking tests; however, the results were statistically significant for only three of the eight subjects.

Kerrigan, et al. (*16*) more recently measured direct arterial blood pressure, heart rate, and cardiac output in 25 habitual smokers at rest and after exercise. Smoking two cigarettes produced statistically significant ($P<0.01$) increases in cardiac index, heart rate, and arterial mean pressure compared to the immediately preceding control period. Exercise after smoking resulted in an increase in cardiac index over either the resting period or the exercise period which followed abstinence; the resultant cardiac index appeared to be approximately the sum of the exercise and smoking effects. Exercise tests preceded by smoking were also associated wtih significantly higher ($P<0.01$) and more prolonged elevations of blood pressure than those not preceded by smoking.

In the study by Goldbarg, et al. (*11*) of nine habitual smokers performing submaximal exercise on a bicycle ergometer, cardiovascular responses were measured via pulmonary and subclavian artery catheters. At rest, after smoking, the mean cardiac index and mean heart rate increased. During successively increasing levels of exercise, the heart rate was greater and stroke index lower than values for comparable work before smoking. The net effect of smoking was to decrease the effiicency of the heart during exercise in the upright position by causing a smaller stroke volume and a higher heart rate.

Rode and Shephard (*26*) investigated near maximal treadmill exercise performance in six habitual smokers. A 1-day abstinence from cigarette smoking was associated with a 13- to 79-percent decrease in the oxygen cost of breathing. Abstinence was also followed by a slowing of the heart rate and a decrease in expiratory minute volume after exercise.

The study of Krumholz, et al. (*18*) is different from those cited previously in that bicycle ergometer exercise performance was measured in habitual smokers both before and after 3 to 6 weeks of abstinence. Among the 10 subjects who abstained from smoking for 3 weeks, there was a statistically significant ($P<0.05$) decrease in heart rate, oxygen debt, and ratio of oxygen debt to total increase in oxygen uptake produced by the 5 minutes of exercise.

Using a "double 9-inch progressive step test" Rode and Shephard (*25*) studied several hundred participants of a smoking withdrawal clinic at the time of entry and at a 1-year followup. Among those who returned for the followup and who gave up smoking, absolute aerobic power increased insignificantly; however, the relative aerobic power diminished in both sexes among those who quit smoking because of the weight gain experienced.

Studies Comparing Smokers to Nonsmokers

Athletic Performance

In 1968 Cooper, et al. (*6*) evaluated 419 airmen during their initial 6 weeks on active duty in the USAF. A 12-minute maximum running test was performed at least 1 hour after cigarette smoking. The mean distance covered in 12 minutes by the nonsmokers was significantly greater ($P<0.05$) than that covered by the smokers at the beginning, the middle, and the end of training. All categories of smokers and nonsmokers improved their performance at the end of training; however, the maximum change in performance of those smoking 10 to 30 cigarettes per day was significantly ($P<0.001$) less than that of nonsmokers.

David (*7*) administered a battery of tests to 88 military personnel, aged 19 to 39 years. A 1-mile run was included in the testing, and cigarette smoking was associated with a significant decrease in performance in this event.

Some 45 special forces soldiers were investigated at sea level and 13,000 feet above sea level by Fine (*8*). The subjects were randomly assigned to a placebo group or an acetazolamide treated group. Cigarette smoking was positively correlated to decrements in 600-yard running performance from sea level to altitude in both groups.

Pleasants (*22*) studied 106 students from intermediate university swimming classes. Swimming times were measured for 100- and 200-yard distances before and after training and for 800-yard distances after training. The mean swimming times of nonsmokers were less than those of smokers in six of seven listed categories, but these differences were not statistically significant.

Bicycle Ergometer Performance

Chevalier, et al. (*5*) investigated cardiovascular parameters in 32 young physicians after a standard 5-minute ergometer test. Oxygen debt accumulation among smokers was significantly ($P<0.01$) greater than among nonsmokers. The heart rate at rest and 3 minutes after exercise was significantly ($P<0.02$) faster in smokers than in nonsmokers.

Using a 5-minute ergometer test, 18 housestaff physicians, half of whom smoked, were investigated by Krumholz, et al. (*17*). They noted the following: Oxygen debt accumulation after exercise was significantly ($P<0.02$) greater in smokers than non-smokers, the ratio of the oxygen debt to total increased oxygen uptake during exercise was significantly ($P<0.001$) greater in smokers than in nonsmokers, and the diffusing capacity at rest and with exercise was significantly ($P<0.05$) decreased in smokers compared to nonsmokers.

Kerrigan, et al. (*16*) studied cardiovascular parameters in smokers and nonsmokers at rest, during, and after a 5-minute bicycle ergometer ride. Cardiac index and blood pressure values obtained during exercise performed immediately after smoking were greater than those found in nonsmokers performing the same exercise. Similarly, heart rate and blood pressure remained elevated for longer periods in those who exercised immediately after smoking than in nonsmokers performing the same task.

Aerobic capacity scores were examined in 60 university student volunteers by Peterson and Kelley (*20*). Subjects worked at submaximal levels on a bicycle ergometer before, during, and after a training program. At all of these intervals, nonsmokers had significantly ($P<0.05$) higher mean aerobic capacity scores than smokers. Both groups increased their aerobic capacity during training but nonsmokers consistently performed better throughout training.

Treadmill Performance

In 1960 Blackburn, et al. (*4*) carried out several measurements of cardiovascular function after different amounts of treadmill exercise were performed by 233 professional men, 159 university students, and 414 railroad workers. The differences between the smokers and nonsmokers were of small magnitude. Basal oxygen consumption was slightly higher in smokers than in nonsmokers. Also, resting pulse rates were higher in smokers of most groups.

Cooper, et al. (*6*) studied 47 out of 419 airmen with treadmill testing. Cardiopulmonary indices measured on the treadmill, including maximum indices, were comparable in smokers and nonsmokers except for a significant ($P<0.01$) reduction in the maximum minute volume among the smokers.

A total of 277 prospective Canadian firemen performed the Balke-Ware test of work capacity in treadmill studies carried out by Glassford and Howell (*10*). The mean performance scores of nonsmokers were significantly ($P<0.01$) greater than those of smokers.

The effect of vitamin C supplementation on treadmill exercise performance was investigated in 40 male volunteers by Bailey, et al. (*3*). Significant differences in oxygen utilization and ventilatory function between smokers and nonsmokers were noted in only two of the 24 separate analyses of variance performed.

Maximal oxygen intake during treadmill exercise was examined by McDonough, et al. (*19*) in 86 healthy, middle-aged male volunteers. Cigarette smoking was one of six variables which together provided a multiple correlation coefficient of 0.73.

Performance in Other Tests of Fitness

When physical fitness tests were administered to 88 military personnel by David (*7*), cigarette smoking was found to be associated with a significant ($P<0.001$) decrease in performance in the dodge and jump test, and a significant ($P<0.02$) decrease in performance in the crawling test.

Using a step test, a breath holding test, and an ergometer test, Franks (*9*) examined 58 middle-aged men. Nonsmokers were able to hold their breath longer and had greater vital capacity residual after the step test than the smokers.

In 1971, Wysokinski (*29*) studied 200 young Polish soldiers using Letunov's test which included 20 knee-bending exercises, a fast run for 20 seconds, and a run for 3 minutes. Cigarette smoking was associated with a significant ($P<0.01$) reduction in the vital capacity and a marked rise in the pulse rate at rest and after exercise. Intense exercise also caused a greater rise in the systolic blood pressure in smokers than in nonsmokers.

Discussion

Most of the studies in habitual cigarette smokers compared exercise performance in "smoking" and "nonsmoking" runs after only a few hours of abstinence. In some studies, smoking adversely affected performance (*11*, *13*, *14*, *16*, *18*, *26*, *28*), while in others it did not (*1*, *12*, *15*, *23*, *24*). Some of these apparently discrepant results are due to differences in methodology and in amounts and types of work performed. In all of the more recent studies of habitual smokers in which moderate to near maximal amounts of work were performed and sophisticated measurements of oxygen transport and cardiopulmonary function were made, impairment of function during smoking trials was found (*11*, *16*, *18*, *26*).

The data of Krumholz, et al. (*18*) also raise the question of whether residual effects of cigarette smoking influence "nonsmoking" trials performed after a few hours of abstinence; they found statistically significant decreases in heart rate and oxygen debt produced by exercise after 3 weeks of cessation.

The work of Rode and Shephard (*25*) suggests that physical fitness improves with cessation, but this improvement may be negated if the subject gains a substantial amount of weight after giving up smoking.

Several investigators compared exercise performance or postexercise cardiopulmonary function of smokers to nonsmokers. Although only minor differences between smokers and nonsmokers were found in a few of these studies (*3*, *4*, *22*), in most of them (*5*, *6*, *7*, *8*, *10*, *16*, *17*, *20*, *29*) the performance or function of the nonsmokers was better than that of the smokers. Both nonsmokers and smokers improved their performance with training, but nonsmokers maintained their advantage throughout training (*6*, *20*).

Biomechanisms

The cited studies indicate that cigarette smoking exerts its adverse effect on exercise performance through several mechanisms. Cigarette smoking appears to impair cardiac performance during exercise by increasing the heart rate and exerting a variable effect on cardiac output (*5, 11, 13, 16, 18, 26, 29*). Cigarette smoking is associated with an increased oxygen debt after exercise (*5, 18*). Also, one study indicated that the oxygen cost of hyperventilation was greater among smokers than among nonsmokers (*26*).

Some of these adverse effects of smoking on oxidative metabolism are mediated by the elevated carboxyhemoglobin levels found in smokers. CO exerts these effects through one or more of the following mechanisms: (*a*) Reduction of the amount of hemoglobin available for oxygen transport, (*b*) shift of the oxygen-hemoglobin dissociation curve to the left with consequent interference in oxygen release at the tissue level, (*c*) induction of arterial hypoxemia, and (*d*) possible interference with the homeostatic mechanism by which 2,3,DPG controls the affinity of hemoglobin for oxygen (*27*). Because carboxyhemoglobin has a half life in the body of at least 3 to 4 hours, its influence may still be measurable several hours after abstinence from smoking (*27*).

A recent investigation of maximal muscular exercise during CO intoxication in five male volunteers demonstrated reduced maximal O_2 consumption in spite of a much higher heart rate and a relative hyperventilation (*21*).

Astrand and Rodahl (*2*) commented recently on the adverse effect of cigarette smoking on oxygen transport: "All other factors being equal, a reduction in the oxygen-transporting capacity is associated with a corresponding reduction in physical performance capacity during heavy or maximal work * * *. Because a regular physical training program only increases the maximal oxygen uptake by some 10 to 20 percent, a 5- to 10-percent reduction in maximal aerobic power due to smoking may play a significant role in many types of athletic events and in very heavy work."

Other studies cited in this review document the adverse effect of smoking on pulmonary diffusing capacity (*18*) and on pulmonary function with exercise (*6, 29*).

Summary

Clinical studies in healthy, young men have shown that cigarette smoking impairs exercise performance, especially for many types of athletic events and activities involving maximal work capacity. Some of these effects are mediated by reduced oxygen transport and reduced cardiac and pulmonary function.

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